SEDIMENTS IMPOUNDED BY AN OFFSHORE BREAKWATER

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ABSTRACT

The breakwater and entrance jetties for the Channel Islands Harbor in California form a total littoral barrier to longshore sand transport. The sand impounded by these structures was monitored by repetitive bathymetric surveys and systematic surface sand sampling. This paper discusses patterns of sediment deposition behind an offshore breakwater. Data collected were studied to determine if the deposition observed agrees with that predicted prior to construction. Both the geometry and size distribution of the deposition sediment are examined.

Three dimensional computer plots are used to illustrate filling patterns. Sediment size and sorting distribution which occur during filling are investigated. Analyzed data allows an evaluation of predicted verses actual filling patterns. Sediment distribution in the impoundment area was evaluated.

BACKGROUND

At Channel Islands Harbor in Southern California, entrance jetties and an offshore breakwater are used to provide a solution to a downcoast beach erosion problem and to provide a small craft harbor. This harbor is located about 60 miles (100 km) northwest of Los Angeles and 1 mile (1.6 km) upcoast of Port Hueneme (Figure 1). The harbor was constructed for the dual purposes of beach erosion control and small craft harbor. Prior to Channel Islands Harbor construction a serious erosion problem existed downcoast of Port Hueneme, which was attributed to diversion of littoral sands into the Hueneme Canyon by

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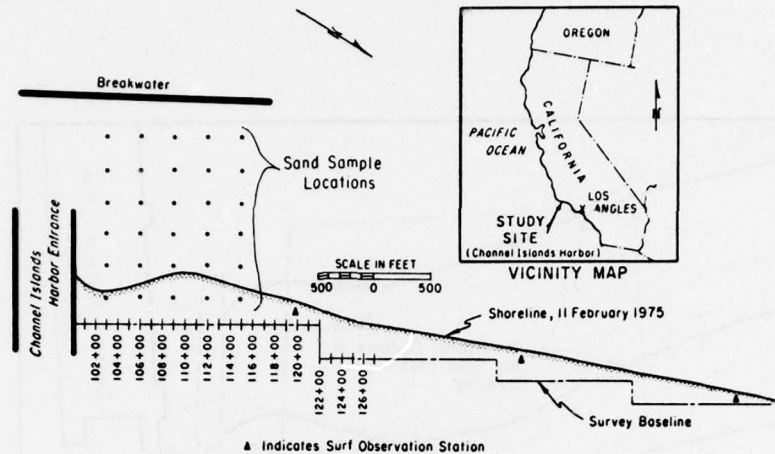
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Figure 1.   Study Area

the Port Hueneme north jetty.    Presently,  sands trapped
at Channel  Islands Harbor  are bypassed  to the south of
Port Hueneme by periodic dredging.

The offshore breakwater  is located at a depth of 30
feet (9 m); it is 2300 feet (700 m) long, about 2000 feet
(600  m) from shore,  and  trends roughly parallel to the
shore.      The design  of the  sand trap was  developed
empirically by considering the configuration of the Santa
Monica,  California  breakwater fillet and by developing
diffraction patterns   for generally prevailing waves
(Corps  of Engineers,  1948;  Herron and Harris,  1966).
Figure 2  shows the predicted fillet developed for design
of the  sand trap and  offshore breakwater.    During the
period from April 1974 to September 1975,  between  sand
trap dredgings,  repetitive hydrographic and topographic
surveys were conducted and surface  sediment samples were
taken.    Surveys were made by  measuring elevations along
22 shore-normal profile  lines spaced at  100 foot (30 m)
intervals (Bruno  and  Gable,  1976).    These  profiles
covered the full extent of the trap and beyond the dredge
area.    Sand samples were  taken  on a  grid of 30 points
with a spacing of 300 feet (90 m)(Figure 1).

(after Corps of Engineers, 1948)

Figure 2.  Design of Channel Islands Harbor Sand Trap
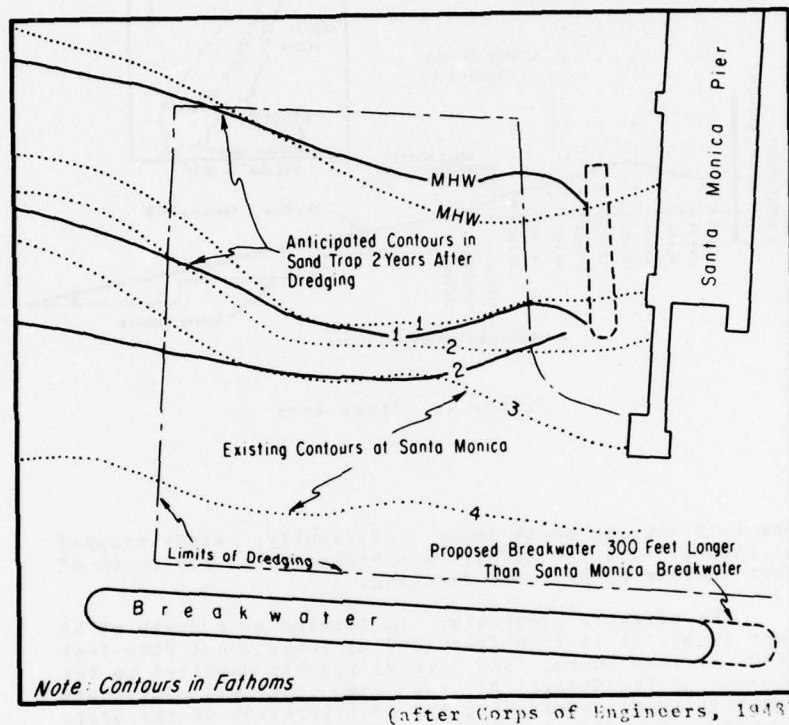
## NEARSHORE ENVIRONMENT

Figure 1 shows the sites where twice daily nearshore data were collected using procedures developed under the Coastal Engineering Research Center's (CERC) Littoral Environment Observation (LEO) program (Bruno and Hiipakka, 1973; Berg, 1968). These data include observations of surf conditions, local winds and littoral currents.

By looking at the plot of monthly averages on breaker height, period and direction (Figure 3), two seasons can be identified. These can be considered as the general summer and winter conditions. From November to May storms with larger breakers (7-10 feet, 2-3 m) and breaker angles greater than 92 degrees are observed. However, from June through October summer conditions persist. These are smaller breakers (2-4 feet, 1 m), and monthly average wave directions are less than 92 degrees.

## DEPOSITION GEOMETRY

The geometry of sand fillet formed behind the offshore breakwater is illustrated with the use of three dimensional computer plots. For each geometry two plots were drawn, first a perspective view of all profile lines, then shore parallel grid lines were added to give the appearance of a surface. Figure 4 shows the post dredge configuration in April 1974. The many irregularities in this surface are the result of dredging. The dredged area covered stations 102+00 to 118+00. Dredge cuts were terminated about 1100 feet (350 m) from the baseline thus leaving a shore parallel ridge at 1150 feet (360 m) from the baseline.

By February 1975 the trap area shows significant filling and smoothing (Figure 5). The fill is occuring along the shore as the beach builds seaward. Also fill can be seen forming a pronounced offshore bar/plateau at a depth of about 10 feet (3 m). The presence of the ridge at 1150 feet (360 m) offshore is still evident.

The September 1975 survey of the fillet is shown in Figure 6. The only remnant of the dredge hole can be seen on stations 103+00 and 104+00. The ridge at 1150 feet (360 m) has now lost its identity. The shore has prograded in a bulge with its apex at station 103+00. At the 10 foot (3 m) depth contour a plateau can be seen seaward of this bulge.
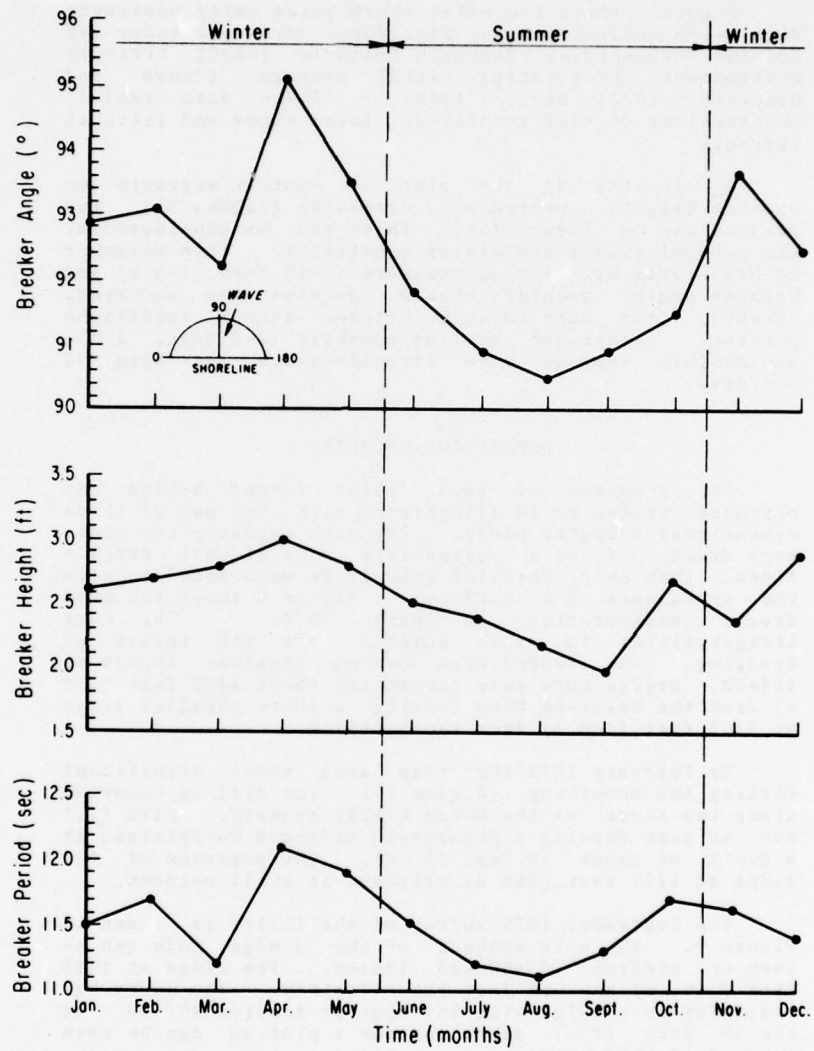
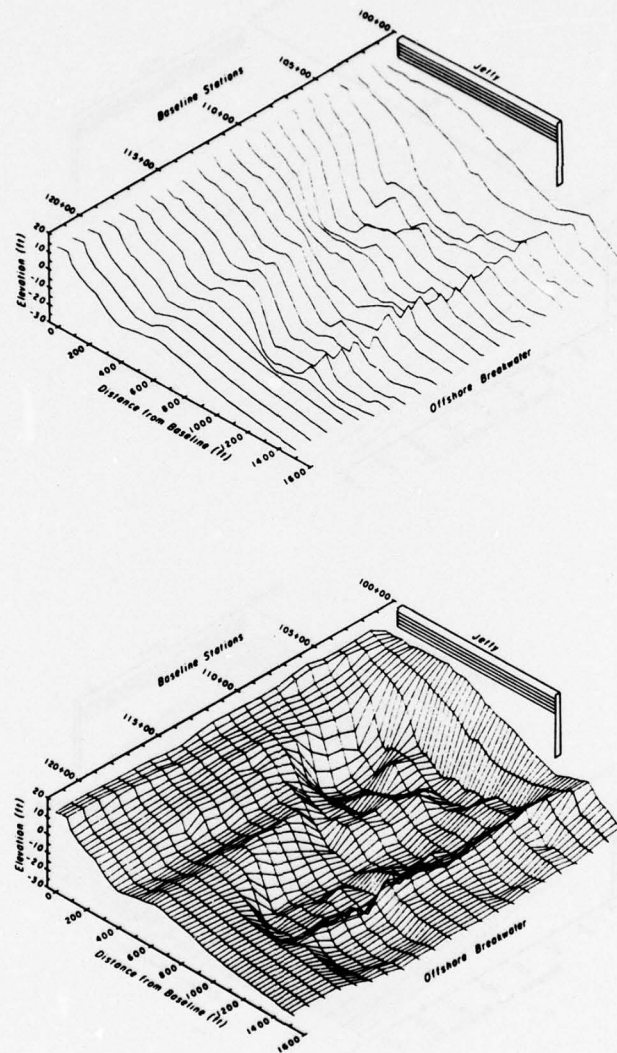Figure 3.  Monthly Average Littoral Observations
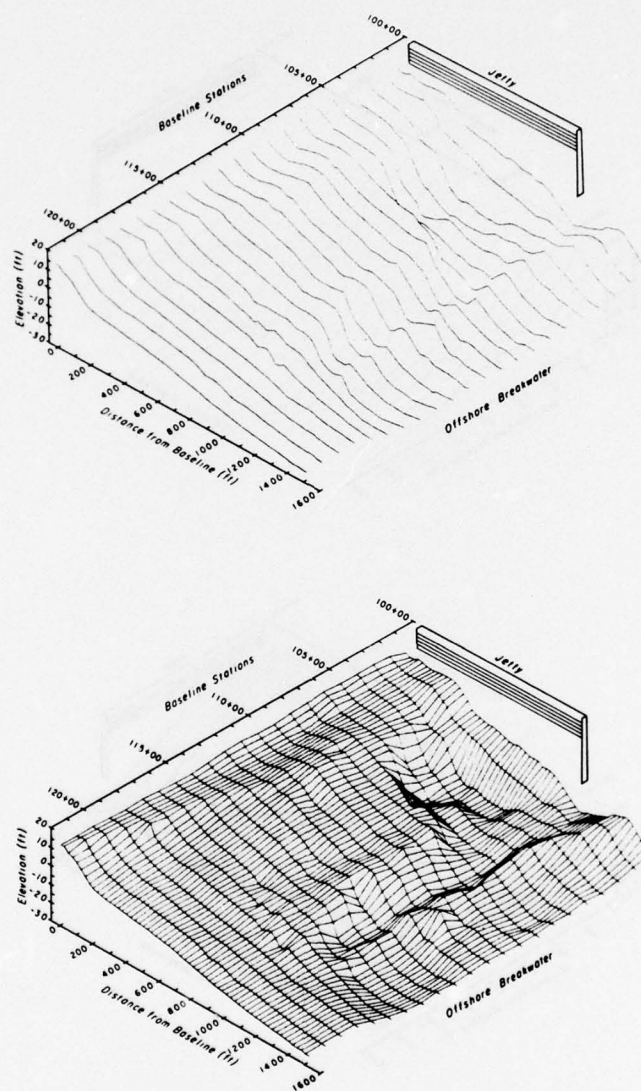
Figure 4. Sand Trap, 17 April 1974
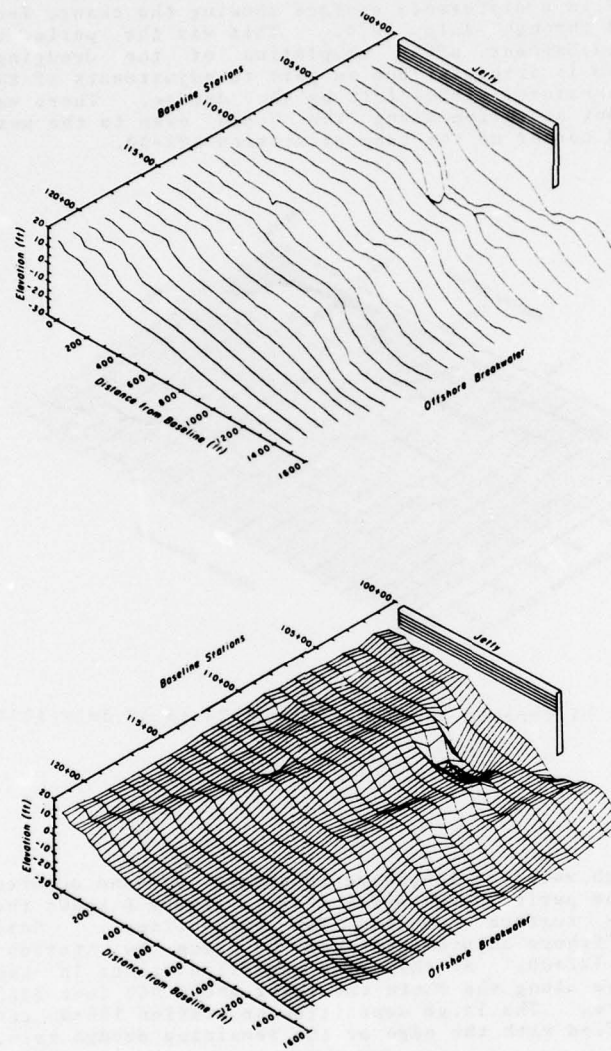
Figure 5.    Sand Trap, 11 February 1975

Figure 6.  Sand Trap, 16 September 1975

Deposition can be examined by subtracting two surfaces and plotting the resulting difference surface. Figure 7 is a difference surface showing the change from May 1974 through July 1974. This was the period of initial adjustment after completion of the dredging. Deposition is irregular due in part to adjustments of the steep, unnatural slopes left by the dredge. There was significant accretion along the beach even to the most sheltered corner of the trap at station 103+00.
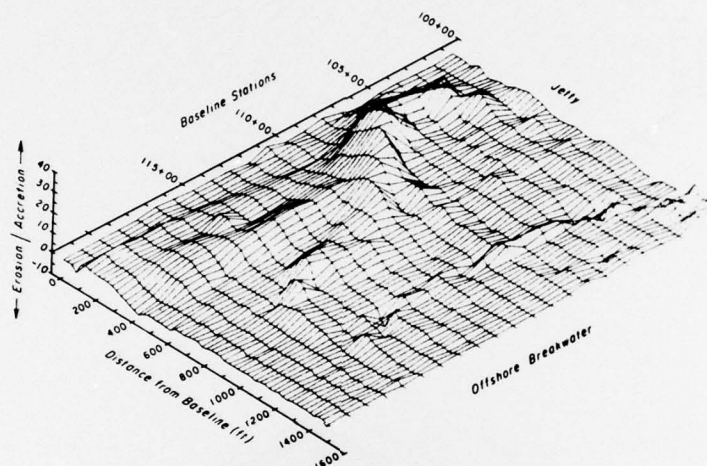


Figure 7. Difference Surface, 7 May 1974 to 30 July 1974

A high rate of longshore transport of sand occured during the period March-April 1975. Figure 8 shows the difference surface computed for this time. Some onshore-offshore adjustments can be seen on stations 117+00 to 122+00. At this time accretion occurs in two bands, one along the shore the other about 900 feet (280 m) offshore. The large deposition on station 106+00 can be identified with the edge of the remaining dredge hole.
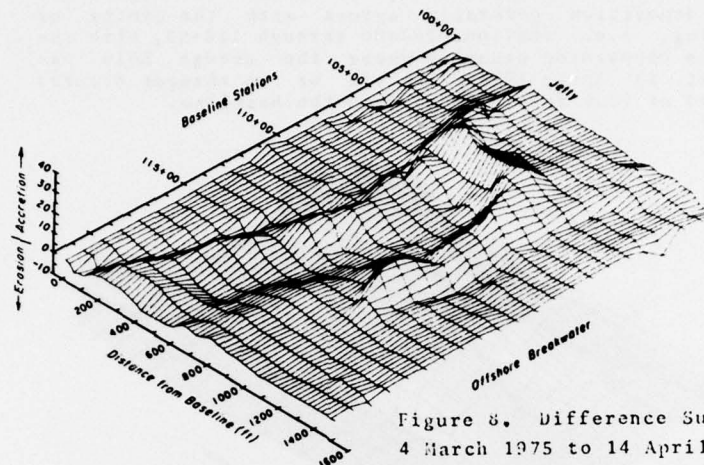
Figure 8. Difference Surface,
4 March 1975 to 14 April 1975

In contrast, Figure 9 shows a period of low
transport, August-September 1975. Here the only
significant change occured at the edge of the dredge hole
on station 104+00. Part of this deposition is attributed
to slumping into the hole as evident from adjacent
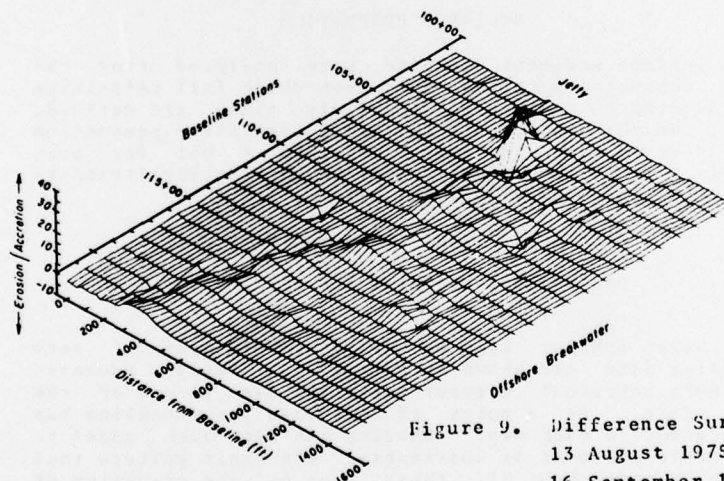erosion shown on station 105+00.



Figure 9. Difference Surface,
13 August 1975 to
16 September 1975

The total change experienced over the study period,

April 1974 to September 1975, is shown in Figure 10. This deposition generally agrees with the limits of dredging, i.e. stations 102+00 through 118+00, with the maximum deposition occuring where the dredge hole was deepest in April 1974. Little or no changes occured seaward of 1200 feet (370 m) from the baseline.
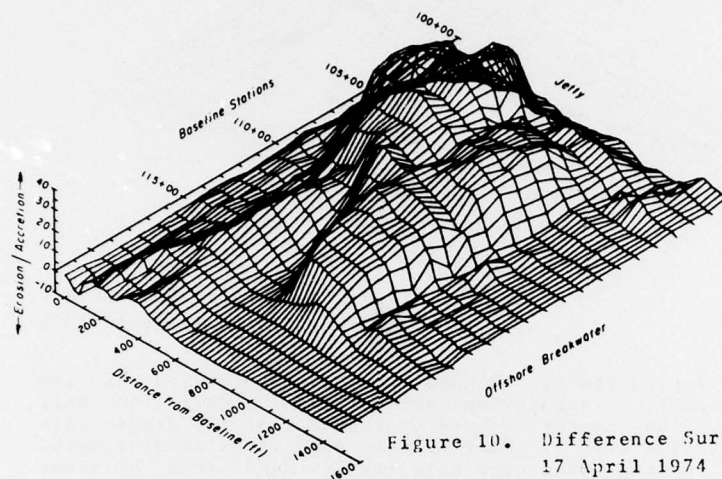


Figure 10. Difference Surface, 17 April 1974 to 16 September 1975

## SEDIMENT PROPERTIES

Surface sediment samples were analyzed using the CERC automated settling tube from which fall velocities are determined and hence particle sizes are derived. Using the phi scale, a ½ phi class cumulative percentage is assigned over the range of -1 to 4 phi for each sample. From this analysis, means and sorting (standard deviation) are derived as follows:

phi mean = (phi 16% + phi 84%)/2

phi sorting = (phi 84% - phi 16%)/2

Seven contour maps of surface sample means at each sampling date are shown in Figure 11. Smaller numbered contours represent coarser materials due to use of the phi scale. As a point of reference the shoreline has been added to each map. Shading has also been added to delineate patterns of coarseness. The basic pattern that prevails throughout all these maps is the gradation of sediments from coarse onshore to fine offshore which is

a. June 1974

b. July 1974

c. November 1974

d. January 1975

e. March 1975

f. May 1975

g. September 1975

*Notes*:

Contours in Phi
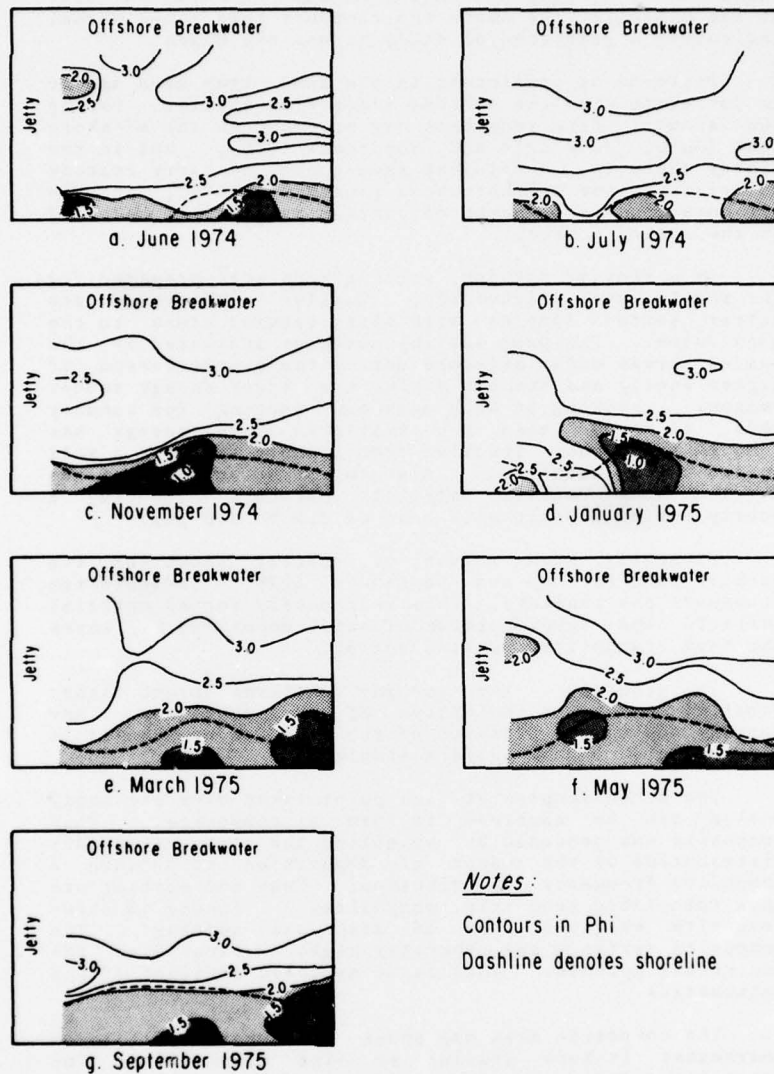
Dashline denotes shoreline

Figure 11.   Contours of Sample Means

typical of an open coastline. In the January 1975 map there is a deviation from this shore parallel pattern. At the bulge in the shore the contours turn shore normal indicating a gradation of sands across the beach.

Patterns of coarseness in the sand trap area appear to correlate with the seasons identified earlier. During the summer, fine sediments may be found in the offshore zone (June, July 1974 and September 1975), but in the winter there is sufficient wave energy to carry coarser materials to the offshore area (January, 1975), and the offshore zone is composed of coarser material as compared to the summer season.

In a similar fashion, sorting maps were prepared for the sample dates (Figure 12). Smaller numbers indicate better sorted samples with sizes ranging close to the mean value. The poor sorting patterns indicated by the shaded areas occur offshore during the winter season of higher energy and inshore during the lower energy summer season. Looking at both mean and sorting for January 1975, it can be seen the available wave energy has removed the finer fraction from inshore and left a well sorted coarse material. Also this type environment has carried some coarser materials offshore producing a poorly sorted deposit with mean of 2.5 to 3.0 phi.

Extremely high values of sorting shown for the onshore zone for May and September 1975, indicate two transport environments. This very poorly sorted material reflects the superposition of sands deposited by waves and that transported by wind action.

In general, the sorting patterns trend shore parallel which is indicative of beach processes. Any sorting due to the presence of the offshore breakwater is not reflected in the surface samples.

The seven samples at each point taken over the study period can be combined to form a composite. This composite was produced by weighting the class frequency distribution by the amount of deposition to produce a composite frequency distribution. Mean and sorting are then calculated from this composite. Figure 13 shows composite weighted maps of mean and sorting. The composite sortings are generally higher values than the individual episode. This is an expected artifact of the mathematics.

The composite mean map shows the general pattern of coarseness inshore grading to fine offshore. The composite sorting map shows that the deepest dredge hole at the outset of the study contains the poorest sorted material. This indicates that all materials which were

a. June 1974

b. July 1974

c. November 1974

d. January 1975

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*Notes:*
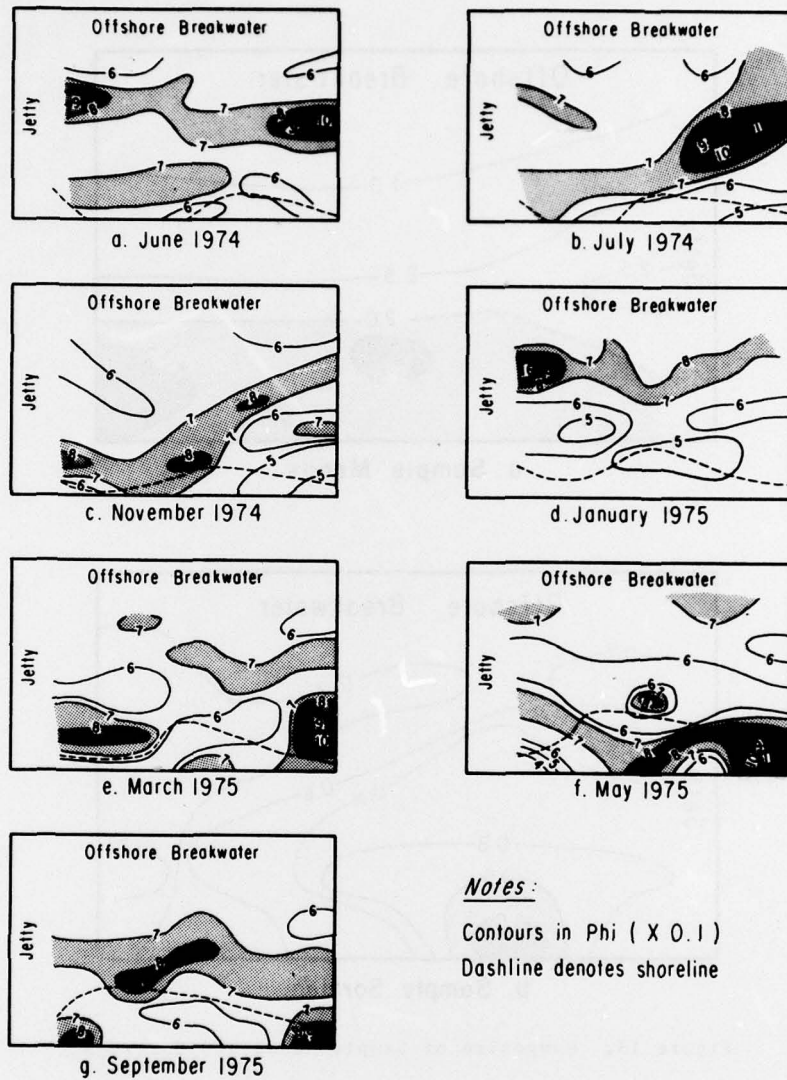
Contours in Phi ( X 0.1 )
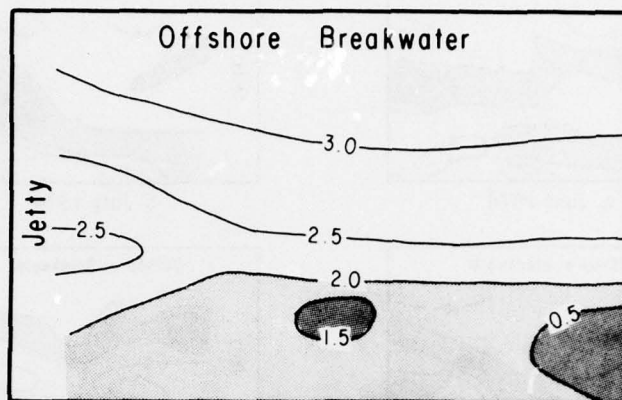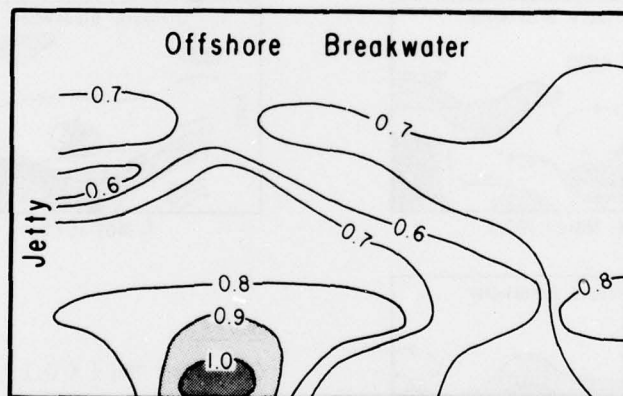Dashline denotes shoreline

Figure 12. Contours of Sample Sortings

a. Sample Means



b. Sample Sorting

Figure 13.  Composite of Sample Means and Sortings

brought to this point were deposited,    whether they were
fines brought in under low energy currents or coarse
material transported by high energy waves.

In studying the composite mean values a linear trend
is evident.    Therefore, a best-fit linear surface was
determined (83% sum of squares reduction) and is shown in
Figure 14a.    The residuals of this fit are shown in
Figure 14b.    This residual map indicates with negative
values those areas where the material was coarser than
the linear fit.    The strong negative values shaded are
indications that gradation is occuring across the trap as
well as onshore-offshore.

## ACTUAL VS DESIGN FILL

Figure 15 shows the predicted designed sand trap
geometry and the actual fillet as measured in September
1975.    The -12 foot (-4 m) contour shows good agreement
with its predicted position at stations 112+00 to 120+00.
Presumably this contour would prograde to nearly the
predicted position inside the trap as the trap continues
to fill.    The remnant of the dredge hole persists
throughout the study and can be seen in the September
1975 contours, but was not predicted in the original
design.  As a result of this hole the -12 and -6 foot (-4
and -2 m) contours are closely spaced indicating a much
steeper slope on the seaward side of the fillet.

In the upcoast region of the fillet the -6 foot (-2
m) and MHW contours are displaced considerably seaward of
predicted values.    This indicates that more of the fill
occured onshore and in depths of less than 6 feet (2 m)
than was expected.    In this respect, Herron and Harris
(1966) reported that the refilled trap area extended well
beyond predicted contour lines during the first and
second dredge cycles in 1963 and 1965.    For those dates
the sand trap was dredged to a depth of -30 feet (-9 m).
Since 1965 the trap has been dredged to a depth of -35
feet (-11 m).

## DREDGING PATTERN

It is desirable to place the material dredged from
the Channel Islands sand trap on the feeder beach
downcoast of Port Hueneme where it has the same textural
properties as that of the natural nearshore material
upcoast of the Channel Islands Harbor trap.    The data
analysis presented shows that the material contained in
the sand trap area tends to be coarser from onshore to
offshore and from upcoast to downcoast.    This coarse to
fine distribution, however, is certainly not well defined
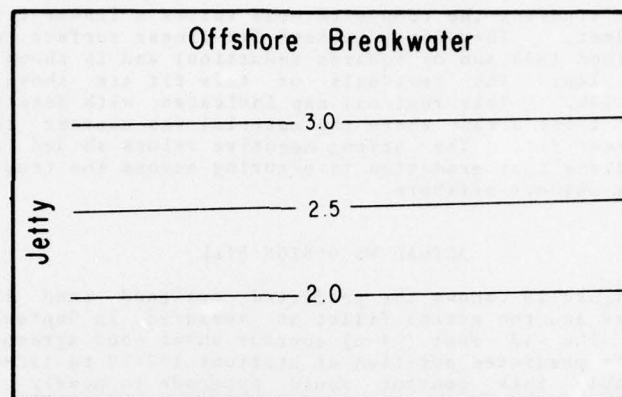
a. Trend Surface
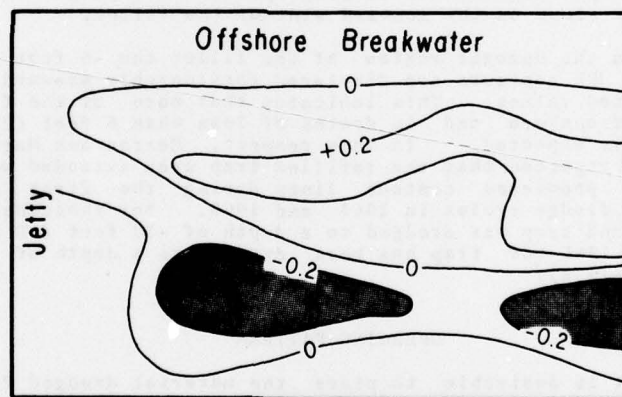


b. Residuals

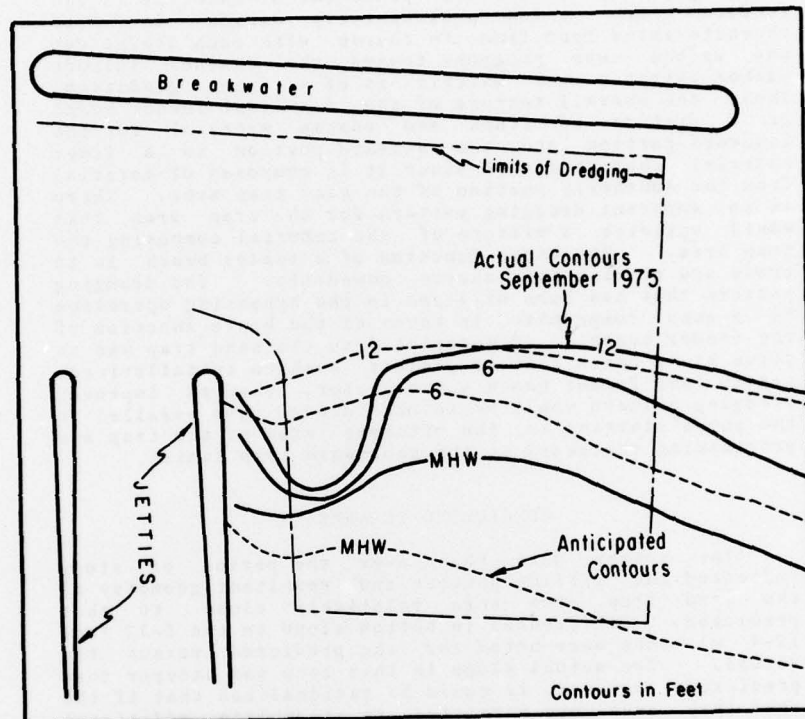Figure 14.   Trend Surface and Residuals of Composite Means

Figure 15.  Actual and Predicted Sand Trap Fill

by the surface sand sample data.  To achieve a well mixed
bypass material for the feeder beach would require
simultaneous dredging from the fine and coarse material
areas.   This, of course, is not possible with a single
pipeline dredge.   The pattern that has generally been
utilized at the Channel Islands Harbor sand trap is to
make a series of cuts normal to the shore with the cuts
starting at the updrift side of the sand trap area.  This
dredging pattern results in placement of material in the
feeder beach which progressively varies in size
characteristic from fine to coarse with each dredge cut
and as the cuts progress toward the Channel Islands
Harbor entrance the material is of a finer gradation.
Thus, the overall texture of the resultant feeder beach
is a mixture of fines and coarse material for the
landward portion and the seaward portion is a finer
material characteristic since it is composed of material
from the southerly portion of the sand trap area.   There
is no apparent dredging pattern for the trap area that
would optimize a mixture of the material composing the
trap area.   The basic function of a feeder beach is to
erode and nourish the shores downdrift.   The dredging
pattern that has been utilized in the bypassing operation
is a good compromise in terms of the basic function of
the feeder beach.   If material from the sand trap was to
serve as a beach fill to protect onshore installations,
say in the feeder beach shore sector, then an improved
dredging pattern would be to make dredge cuts parallel to
the shore starting in the offshore area of the trap and
progressing shoreward to the shoreward trap limits.


CONCLUDING REMARKS


     The survey data taken over the period of study
indicated the filling pattern and resultant geometry of
the sand trap area were relatively close to that
predicted.   Differences in bottom slope in the 6-12 foot
(2-4 m) zone were noted for the predicted versus the
actual.   The actual slope in this zone was steeper than
predicted; however, it could be rationalized that if the
sand trap area were permitted to accumulate additional
material and adjust to the incident wave energies, the
predicted and actual bottom slopes of the impoundment
area would probably be in close agreement.

     The design and physical features of the Channel
Islands Harbor offshore breakwater and entrance jetty
system would suggest that there should be a distinct
pattern of coarse to fine composition for the littoral
materials impounded in the trap area.   The sand sample
data do not clearly confirm this suggestion.   The data
indicates a trend of the pattern but the results were not
as distinct as one would have predicted.  One influencing

factor for this could be the high wave energy environment at the study site. Bottom cores are scheduled to be taken in the trap area prior to the next dredging (September, 1977) of the trap and these core data will be analyzed to further evaluate the material distribution pattern in the trap area.

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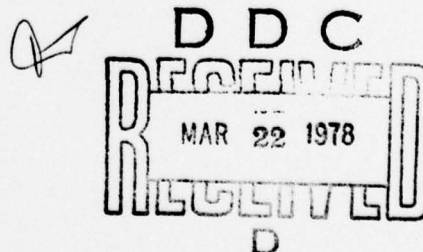
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